TORNADO PREPAREDNESS AND PUBLIC WARNING SYSTEMS FOR THE FREDERICK-FIRESTONE FIRE PROTECTION DISTRICT

EXECUTIVE ANALYSIS OF FIRE SERVICE OPERATIONS IN EMERGENCY MANAGEMENT

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Abstract

The problem was the Frederick-Firestone Fire Protection District (FFFPD) has not updated its tornado public warning system since 1981. The purpose of this applied research project was to identify tornado preparedness activities and types of tornado public warning systems available for use by the FFFPD. This was a descriptive research project. The research questions were: (a) what tornado response planning and preparedness activities are being used by communities in the United States, (b) what types of public warning systems for tornado threats are being used in the United States, and (c) what methods are being used to fund the initial purchase and continued maintenance of tornado warning systems? A feedback form (Appendix) was developed by the researcher to gather data on tornado preparedness activities and warning systems. A convenience sample of 86 participants was used for this study. Descriptive statistics were used to calculate and interpret the data generated from the feedback form. The results showed 60.3% of the respondents claimed their jurisdiction had a tornado preparedness and response plan. Eleven major components of those plans were identified. 73.8% of respondents stated their jurisdiction had a public warning system. Five major components of tornado warning system were identified. Grants, general funds from taxes, bonds, and donations were the funding methods used to purchase and maintain warning systems. The recommendations included the FFFPD develop a tornado preparedness and response plan. It was further recommended the FFFPD develop a multi-component public warning system. Grants were the recommended funding sources for these programs. Future research recommendations included public education programs, tornado recovery procedures, and advanced sheltering and evacuation procedures.

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Introduction

The problem is the Frederick-Firestone Fire Protection District has not updated its tornado public warning system since 1981. In the time period since the last update, the FFFPD's district boundaries have expanded from five square miles to 32 square miles. As a result, much of the added area lies outside of the audible coverage area of the existing public alert sirens. Adding additional warning sirens to provide audible warning to all areas within the FFFPD's coverage area will be a costly investment. Additionally, there have been advances in technology and tornado preparedness and warning systems that will allow the FFFPD to invest funding and resources more wisely to provide the public residing within the jurisdiction a multi-faceted public warning system.

The purpose of this applied research project is to identify tornado preparedness activities and types of tornado public warning systems that are available for use by the Frederick-Firestone Fire Protection District. This is a descriptive research project. The research questions are: (a) what tornado response planning and preparedness activities are being used by communities in the United States, (b) what types of public warning systems for tornado threats are being used in the United States, and (c) what methods are being used to fund the initial purchase and continued maintenance of tornado warning systems?

Background and Significance

The Towns of Frederick and Firestone are in the southwestern most portion of Weld County, Colorado on the Great Plains adjacent to northern Colorado's Front Range of the Rocky Mountains. Both communities are statutory Towns with Frederick signing its charter in 1907 and Firestone in 1908 (Town of Firestone, 2007). This area, commonly known as Carbon Valley, began as a large mining area near the turn of the 20th century. Today the Carbon Valley area is experiencing large residential and commercial growth as urban sprawl spreads out from the

Denver metropolitan region. The combined area of the two towns is currently 30 square miles with planning areas for future annexations totaling 72 square miles. The 2007 populations of both towns equaled 16,997 residents with an average growth rate of 16% each year (Town of Frederick, 2007).

Information retrieved from the Frederick-Firestone Fire Protection District (2005) yielded the information in the following paragraph. The Frederick-Firestone Fire Protection District is a Special District formed under the Title 32 Special District Act of the State of Colorado. The Frederick Volunteer Fire Department was first organized in 1915 with eight active volunteer members. In 1976, the residents of a nine square mile area voted to form the Frederick Area Fire Protection District. The District then covered portions of the Towns of Frederick and Firestone, and unincorporated areas of Weld County. The District was formed to provide services supported by property tax revenue collected from the residents living within the boundaries of the District. The District continued to operate as a full volunteer department until 1988 when the District Board of Directors hired the first full time employee. In 1998, the District expanded to 3 full time employees with each working a rotating 24-hour shift. In 2000, the District expanded its full time employee base to six full-time firefighters. In 2003, the Town Board of Trustees of both Firestone and Frederick unanimously approved the Frederick-Firestone Fire District as the sole emergency services provider within the two towns' current and future boundaries. In 2006, the District assumed ambulance transport services from the Tri-Area Ambulance District, which dissolved on December 31, 2005. The District currently covers approximately 32 square miles from three fire stations. The District's service area also includes 4.5 miles of Interstate 25. The District is a combination fire service provider utilizing 25 full-time firefighters supplemented by

a reserve staff of 20, and an administrative staff of six (Frederick-Firestone Fire Protection District, 2005).

The topography of the interface of the Front Range of the Rocky Mountains and the High Plains region of the Great Plains creates a large counterclockwise circulation of air known as the Denver Cyclone and a large clockwise rotation of air to the north called the Longmont Anticyclone. These low pressure areas stretch from Denver to Greeley and produce strong thunderstorm updrafts and vertical wind shear increasing the potential for tornadoes (Parzybok, 2005). The Carbon Valley area rests directly in the middle of these two wind fronts.

In 2006, the Great Plains of eastern Colorado experienced 20 reported tornadoes (Insurance Information Institute, 2006). By comparison, during the 29 year period between 1961 and 1990, 197 tornadoes, an average of 7.9 per year, were reported in Colorado (North Allegany School District, 2003). This information demonstrates a dramatic increase in tornado activity in Colorado in recent years. This increase in activity combined with growing population density poses a serious threat to public safety.

Currently the FFFPD only uses a mechanical civil defense siren system for warning the public of tornado threats in the area. To compound the situation, the siren system only consists of two sirens located in the downtown areas of Frederick and Firestone, and both must be activated manually from Station 1 located in Frederick. According to data provided by the Wikimedia Foundation (2008), tornado sirens of the type used by the FFFPD have a typical audible effectiveness range radius of one-half to one mile. This translates to approximately 24 square miles of the jurisdiction lying outside of the effective range of siren coverage. Additionally, many of the traditional mechanical warning sirens, such as the type used by the FFFPD, were not designed to be heard indoors (Franklin, 2005). In April of each year, the FFFPD performs an

operational test of its warning sirens. Immediately following the April 2007 test, officials of the District received feedback from citizens within a five block radius of the siren located in Frederick claiming they did not hear the siren while inside their home or business, or the sound was barely audible enough to raise curiosity. Add this to the need for manual activation, and the potential risk of a delayed activation and limited coverage could mean the majority of the public would receive little or no siren warning in the event of a tornado approaching the area.

Given a rapidly expanding coverage area, limited manpower, and a growing population, the FFFPD faces many challenges and responsibilities when assessing risk and addressing community safety. With a transitioning agricultural industry and growing commercial and residential zones, the responsibility of tailoring prevention and response programs to meet such diverse needs is tremendous. For example, the hazards faced by farmers using heavy machinery, chemicals, and aging infrastructure is very different from those faced by workers and occupants of commercial occupancies utilizing sprinkler systems, elevators, and a high occupant load. Although the hazards may be different, the risks to life safety have to be addressed equally for all groups. Such diversity means the FFFPD must optimize resources, prioritize risks, and efficiently provide a broad cross-section of programs to enhance life safety and ensure response resources do not become overburdened.

This Applied Research Project relates to Unit 4, Community Risk/Capability Assessment, of the National Fire Academy's Executive Analysis of Fire Service Operations in Emergency Management (EAFSOEM) course. This project's objective is directly associated with the terminal objective of Unit 4 which states: "The students will be able to apply a process to describe and assess risks in their own communities and assess their department's resource capabilities in relation to those risks" (National Fire Academy, 2005, p. 4-1).

Additionally, this research project relates to the United States Fire Administration's (USFA) operational directives "help communities develop comprehensive all-hazard risk reduction plans" and "reduce the loss of life from fire-related hazards, particularly among these target audiences: (a) 14 years and younger age group, (b) 65 years and older age group, and (c) firefighters" (National Fire Academy, 2002, p. II-2). These objectives are accomplished through this research project by identifying preparedness activities capable of better preparing the public for tornadoes and associated threats, and defining methods to increase public warning in advance of tornado activity.

Literature Review

The purpose of this literature review was to present current information from contemporary sources to support the foundation of this study. This researcher sought to find support for the three research questions. First, what tornado response planning and preparedness activities are being used by communities in the United States? Second, what types of public warning systems for tornado threats are being used in the United States? Finally, what methods are being used to fund the initial purchase and continued maintenance of tornado warning systems?

According to a preparedness guide distributed by the National Weather Service (1995), tornadoes have occurred most frequently in areas east of the Rocky Mountains. These destructive storms are capable of producing winds in excess of 250 miles per hour and damage paths between one mile and 50 miles wide (National Weather Service, 1995). The guide divided tornadoes into three general categories: weak, strong and violent. Weak tornadoes were described in the guide as having wind speeds of less than 110 miles per hour (mph) and comprised 69% of all tornadoes. These types of tornadoes accounted for 5% of all tornado

related deaths according to the National Weather Service. In contrast, the guide stated violent tornadoes having wind speeds in excess of 205 mph accounted for only 2% of all tornadoes but 70% of all tornado deaths.

A review of available literature in journals, government reports, books, and previous research papers centered on two groups for the purpose of discussing preparedness and response activities in support of the first research question; individuals and governmental agencies. The literature emphasized risk assessment, public education, and pre-planning activities as the best means to counteract the negative impacts of natural disasters. In research conducted by Balluz, et al. (2000), the researchers concluded families should develop an emergency plan, emergency management agencies should expand public education activities, and "officials planning protection measures for vulnerable communities should consider most people have limited time in which to respond to a tornado warning" (Balluz, et al., 2000, p.71).

The American Red Cross (1999) recommended families develop a disaster plan specifying a designated safe place, method of warning family members of impending severe weather, an emergency phone list, inspection checklist to remove potential hazards within and around the home, training on how to use basic safety measures such as basic first aid and fire extinguisher use, and a disaster supply kit to meet the family's survival needs for at least three days. According to the American Red Cross guide, the family disaster plan should also contain a list of items to secure before a storm, a checklist for protecting property including keeping shrubbery and trees trimmed, removal of debris or loose items in the yard, and installation of permanent shutters to cover windows. The Red Cross also urged families to regularly test their disaster plan with periodic drills designed to reinforce the plan.

In a journal article written by the Contingency Planning Management Group (2007), the authors discussed preparedness activities necessary for businesses in areas prone to tornado activity. The article stated tornadoes reach the highest frequency of occurrence in spring and summer months. The authors affirmed acts of nature cannot be contained or controlled, therefore the most effective means to limit their effects was to enact preparedness activities and be aware of the risk of tornado activity in a particular area. The author proposed several planning measures including the purchase of portable radios, establishment of alternate communications methods should phone lines be interrupted, creation of an emergency contact list, and establishment of safe areas within buildings for occupants to evacuate to in the event of a tornado warning. The authors further recommended establishing a checklist of activities for completion after a tornado has occurred including damage assessment, accountability of personnel, and establishing communication with emergency officials.

Brubaker (1997) stated many businesses may have emergency procedure manuals in excess five to ten years old. Furthermore, the author asserted these procedures are rarely tested. Brubaker advocated businesses adopt an emergency plan and each plan be tested by conducting tornado drills regularly. He listed several components each plan should contain. First, businesses should designate floor coordinators who are responsible for providing leadership and direction in the event of a tornado. The floor coordinators should also be responsible for directing the evacuation of employees and visitors to pre-determined safe areas. Second, Brubaker stated each emergency plan should contain a section defining an early warning system and internal communication system to be used by the business in the event of a tornado warning. The most effective early warning system according to Brubaker was the use of weather alert radios strategically placed in areas of the building that were continuously staffed while the building was

occupied. Furthermore, he said the internal communication system should be able to alert all occupied areas of the building and instruct personnel of an impending tornado and the need to seek shelter. He stated a third component of a business's emergency plan was training. Training sessions, or drills, should be conducted at least annually and should emphasize alarm recognition, alerting of all personnel, when to evacuate, and how to reach the nearest shelter or safe area according to Brubaker. He promoted conducting a formal review of all training sessions in order to identify needed improvements in the emergency plan. Della-Giustina (2000) reiterated the recommendations of Brubaker's article, but added the floor or safety coordinators should also be trained to shut off utility services.

The review of contemporary literature also revealed many recommendations for preparedness and response activities for governmental agencies. In a review of a tornado that struck East Brunswick, New Jersey, Kosik (1997) recommended each community have an up to date Emergency Operations Plan (EOP). The EOP should contain a section for training and exercising personnel regularly, adoption of an Incident Command System, and a communications section designating frequencies and users according to Kosik.

Hnatko (2006) stressed the importance of conducting an annual hazard vulnerability analysis. This analysis should identify potential hazards in a given community and the local emergency agencies' ability to respond to those hazards, remembering "a problem identified is half solved" (Hnatko, 2006, p. 79). Once the hazard vulnerability analysis is complete, the author recommended each agency review their emergency response plan as it related to natural hazards. Each response plan should address each event outlined in the hazard vulnerability analysis according to Hnatko. He also advocated frequent training on the plan through drills and reviews. The author further promoted a multi-agency, multi-jurisdictional approach to drills and training

since a disaster such as a tornado will have widespread effects and it was imperative all responders had an understanding of resources and procedures for mitigating the emergency. Immediately following a drill, the information learned should be discussed in order to revise the emergency response plan according to Hnatko. The “ERP should be a living document, always growing and changing” (Hnatko, 2006, p.79).

Mosier (2002) reiterated the need for pre-planning and an up to date emergency operations plan having sections specifically designed to address natural disasters in each community. He suggested each plan address the three phases of emergency response to a tornado: a pre-storm phase, a warning phase, and a response phase. Mosier elaborated the pre-storm phase should include conducting risk assessments, drills, and public education. The warning phase needed to contain a method for receiving weather information and alerts such as the utilization of weather alert radios or Internet based weather tracking software according to the author. He also advocated dispersing personnel and equipment throughout the community during the warning phase. Mosier stated the response phase of the plan should address potential hazards likely to be present after a storm including downed power lines, natural gas ruptures, and weakened structures. Additionally, the author suggested adequate communications equipment be in place in order to ensure personnel accountability and thorough damage assessments after the storm.

In an analysis of the Palm Sunday tornado that struck Piedmont, Alabama, Rigg (1997) advocated involving dispatchers and dispatch centers in the planning process for tornado preparedness. According to the author, the dispatch center often received the first alert from the National Weather Service and the dispatcher was often responsible for activating alert devices for local jurisdictions. Rigg also stressed the importance utilizing the media in public education

and awareness of the various methods of warning of potentially dangerous weather. “A tornado watch is like a yellow alert, it means that conditions favor the development of severe storms, which can produce tornadoes. A tornado warning is a red alert, meaning that conditions are imminent or already in progress and you should take cover immediately” (Rigg, 1997, p.32).

In support of the second research question, the review of contemporary literature emphasized the use of multiple methods of public warning in the event of tornado activity, since there was no single method that was 100% effective in all situations (Mosier, 2002). In a study examining public reaction to two tornadoes that struck Moore, Oklahoma in 1999 and 2003, Comstock (2005) listed the most common forms of tornado warning systems as: Television broadcasts, tornado sirens, observable weather changes, commercial radio broadcasts, phone or pager alerts, and weather band radios. Comstock found of the people who received warnings of the impending tornado, 93% received them from television and 73% from tornado sirens. She stated only 2% of respondents in the study reported receiving warnings from weather band radio. The researcher explained respondents reported receiving detailed information about the approaching storm and instructions on what to do from the television alerts. In contrast, Comstock reported tornado sirens were activated only minutes before the tornado struck and were not capable of providing any detailed information. As a result, the tornado sirens added to confusion and panic according to the researcher. A study conducted by Balluz, et al. (2000) researching public reactions to a tornado striking Arkansas in 1997 found similar results. Eighty-one percent of respondents reported receiving warning from television broadcasts and 72% from hearing tornado sirens according to the researchers.

A research project conducted by Paul, et al. (2003) studied public response to the May 4, 2003 tornadoes that struck Kansas, Missouri, and Tennessee. The researchers discovereds types

of warning systems and emergency personnel qualifications were correlated to community size. The researchers further discovered larger cities were often equipped with advanced tornado warning systems such as television broadcasts with access to sophisticated weather radar systems, whereas small rural communities relied predominantly on traditional, less reliable warning systems such as sirens. Paul, et al. stated a main pitfall of siren systems was they were used for other purposes such as routine notifications which caused a normalization of the public's response to the siren and disregard for a true warning. One of the reasons given by the researchers for such heavy reliance on older siren systems in rural areas was small towns generally did not receive federal grants for upgrading to newer storm warning systems. "The federal government recognizes that protecting the large more densely populated major cities is vital since tornadoes can usually create more damage and the potential for loss of life is greater there" (Paul, et al., 2003, p. 6). A further complication discovered in the research project was smaller communities rarely had direct access to weather radio broadcasts. Of those polled in the study, a majority stated television broadcasts were the most effective warning sources, and the second was tornado sirens. In every rural community participating in the study, sirens were listed as the most recognized means of tornado warning devices. Like Comstock, Paul, et al. found tornado sirens had several inherent shortcomings including becoming less effective with distance and wind, and such sirens were designed to serve as a warning for persons outdoors, not in buildings. In their conclusion, the researchers recommended implementing programs to educate the public on the benefits of weather radios. They listed the presence of battery back-ups in the event of a power outage, ability to arouse a sleeping person, and the broadcast of detailed instructions as the main benefits of weather alert radios.

Simmons and Sutter (2007) investigated the tornadoes that moved through central Florida on February 2, 2007. The researchers discovered many of the communities struck by these tornadoes did not have sirens to warn the public. The data disseminated by the researchers further found residents from states where sirens are used as a primary means of alerting for a tornado warning assumed their new communities had the same capabilities. This assumption contributed to a false sense of security, and when sirens weren't heard people ignored other warning signs according to the researchers. Simmons and Sutter further found many flaws inherent in warning sirens including new building methods and materials in homes which made them more sound efficient. The researchers shared the recommendations of Paul, et al., that weather alert radios were a superior alternative to sirens especially considering the high cost per resident of sirens in rural areas.

Rigg (1997) stated weather alert radios, which utilized transmitters maintained by the National Weather Service to broadcast weather alerts to specific zip codes within a threatened area, were an effective means to alert the public of a tornado and they were available to the public through local retailers. Rigg advocated placing these radios in public buildings and private homes. Mosier (2002) pointed out weather radios, which depended on receiving a signal from a transmitter, did not have coverage in all areas. In support of this assertion, a study conducted by Tiefenbacher, et al. (2001) found virtually nobody with a weather alert radio received a warning prior to a tornado striking the town of Siren, Wisconsin due to weak reception in the area.

Television broadcasts were among the most effective means of warning the public during severe weather and tornado activity according to Mitchem (2003) in a study of the tornado that hit Indianapolis, Indiana on September 20, 2002. Ely (2000) further stated a cable override system was extremely effective in notifying the public prior to the tornadoes that moved through

Tarrent County, Texas in March, 2000. According to Ely, a cable override system was an alert sent over cable television channels overriding normal broadcasts and instructing viewers of impending severe weather or tornado activity. A research project conducted by Dickerson (2007) concluded the Emergency Alert System managed by the National Weather Service was the most effective means of alerting the public to severe weather due largely to its lower cost and larger coverage compared to a network of tornado sirens.

Scott (2007) focused on dispatch centers and weather monitoring as the first point of contact in activating any tornado warning system. According to the author, in the past tornado warnings were issued to multiple counties over large geographic areas even though only a small portion of the area was actually in an immediate threat zone. This problem, Scott stated, was due to the inability of dispatch centers to alert smaller segments of a jurisdiction. The article focused on the use of software such as *WeatherData's* Select Warn system which allowed dispatch centers to activate sirens remotely in an immediate threat area. Another piece of software listed in the article was *DTN/Meteorlogix* which allowed dispatch centers access to weather data more detailed than that received from the National Weather Service several hours in advance of a storms impact, and could pinpoint a potential impact area as small as five square miles. Scott also discussed software from *WeatherData* designed to send weather alerts to mobile devices such as cell phones, pagers, mobile computers, and personal data accessories (PDAs). As long as a device had a browser, it could receive weather information in real time, according to the author. Software used by the Muskingum County (OH) Sheriff's Department assisted dispatchers and field units in interpreting large volumes of weather information from multiple sources and prioritizing responsibilities according to Scott. He stated this same software, also offered by *WeatherData*, accurately predicted the levee breaks in New Orleans (LA) caused by Hurricane

Katrina long before they actually failed. Other Internet based weather alert software providers discussed by Scott included *MyWeather, LLC, WeatherBug,* and *AccuWeather*. He elaborated *MyWeather* offered hourly weather updates to subscriber e-mail and mobile devices. *WeatherBug,* which used over 8,000 tracking stations, provided live weather updates to mobile devices as well as camera images of local weather conditions according to Scott. *AccuWeather* provided online local weather forecasts according to the article. Mosier (2002) recommended using Internet software such as the Emergency Managers Weather Information Network (EMWIN) which provided real time severe weather data.

In response to the third research question, the review of contemporary literature provided a narrow list of funding sources for the local government to use to fund methods of public warning systems. The various types of warning systems listed previously have a wide range of cost depending on the type of system. As an example, Audiotech Digital Signal Corporation (2008), a major manufacturer and distributor of outdoor warning sirens offered pricing of $4,910 for a fixed omni-directional siren with an effective range of 2,500 feet, $6,100 for a fixed omni-directional siren with an effective range of one half mile, and $13,060 for a rotating siren with an effective range of 5,600 feet. Additionally, Scott (2007) stated weather alert software has a wide range of pricing options; however the average seemed to be about $500 per month or between $5,000 and $6,000 per year, per agency. He further explained systems for use by the general public were often free or sponsored by governmental agencies and offered free to the public. With regard to a third type of public warning device, Radio Shack (2008), a reseller of weather alert radios had pricing between $13.99 and $69.99 for these devices, depending on portability and extra features desired by the purchaser.

As mentioned earlier by Paul, et al. (2003), a major reason for the heavy reliance on tornado sirens as the main means of alerting the public in rural areas was the scarce availability of federal grants for more reliable systems in such communities. Yet as stated by Paul, rural or smaller communities were in more need of alternate public warning systems due to a lack of access to inherent systems found in large communities such as local television and radio stations having access to localized advanced radar. The Stafford Act of 1988 was established as a mechanism for the federal government to distribute financial assistance to an area affected by a disaster (Wikimedia Foundation, Inc., 2007). The Hazard Mitigation Grant Program was created under the Stafford Act **"**to reduce the loss of life and property in future disasters by funding mitigation measures during the recovery phase of a natural disaster" (Federal Emergency Management Agency, 2007, p.1). According to the FEMA publication, the grant funds were administered through individual states and had a 25% matching requirement, meaning the federal government provided 75% of the funding for a project's cost and the state or local authority funded the remaining 25% of the project. Additionally, the Pre-Disaster Mitigation Program offered through the federal government was established to assist communities with hazard mitigation activities and programs before a disaster occurs (Federal Emergency Management Agency, 2007).

Another funding option found in the review of contemporary literature to provide public warning systems was the U.S. Department of Agriculture Rural Development Grant program (U.S. Department of Agriculture, 2007). As an example on the U.S. Department of Agriculture's website, Jackson County (TN) received a grant in 2006 from this program to construct a tornado warning system. According to U.S. Department of Agriculture, the Rural Development Grant was intended to support essential public facilities and services to help rural communities

undertake community empowerment programs. An additional grant resource for funding public alert systems was offered through the U.S. Department of Health and Human Services. As a part of the President's 2002 Fiscal Year Management Agenda to improve government services to the public, *Grants.gov* was established by the U.S. Department of Health and Human Services as a resource that gave individuals and agencies access to over $400 billion in grant monies available through 1,000 different grants (U.S. Department of Health and Human Services, 2002). The website allowed the user to search various grant categories by topical search, including disaster prevention such as tornado warning systems. The website listed open dates and requirements for each grant, and also allowed the user to apply online.

Rigg (1997) stated Alabama was in the final stages of installing National Weather Service Transmitters statewide. The program as part of a larger initiative to install weather alert radios in all private homes and public buildings in the state with financial support given to local communities through state funding and support from FEMA according to Rigg. To date, the author stated 95% of the state was covered by the transmitters.

In summary, the review of contemporary literature supported the first research question offering several components of preparedness and response planning. The common theme portrayed by contemporary researchers on this topic was the need for families and businesses to develop disaster or emergency plans. These plans should contain detailed checklists, individual assignments, communication procedures, supply kits (American Red Cross, 1999), and most importantly training and testing of the plan (Brubaker, 1997). Furthermore, the literature review recommended governmental agencies and first responders conduct a periodic hazard vulnerability analysis and other pre-planning activities to determine potential threats to the community and capabilities to respond to those threats (Hnatko, 2006). An important component

of preparedness and response activities for governmental agencies to implement was an extensive public education program to inform the public of potential threats and what individuals can do to protect themselves (Mosier, 2002). Several types of tornado warning systems were cited in response to the second research question. Mosier (2002) emphasized the utilization of multiple methods of warning the public to impending tornado activity since each individual method had some shortfalls. Comstock (2005) listed television broadcasts, tornado sirens, observable weather changes, commercial radio broadcasts, phone or pager alerts, and weather band radios as the most common methods used to warn the public. Sirens tended to be the most widely used and recognized tornado warning method (Paul, 2003) even though they were not the most effective and among the most costly (Dickerson, 2007). Finally, several funding sources for the purchase of public warning systems were cited in response to the third research question. Pricing for outdoor warning sirens varied widely depending on effective range and directional ability, starting at $4,910 and extending to $13,060 per unit (Audiotech Digital Signal Corporation, 2008). Television broadcasts including the use of cable override technology and the Emergency Alert System, proved among the most effective method of public warning (Mitchem, 2003). Emerging technologies such as software designed to send alerts to cell phones, pagers, and computers were an effective means for both the public and governmental agencies to receive real time weather information and alerts (Scott, 2007). Pricing for such software, according to Scott, ranged from free to $6,000 per year depending on complexity. Weather alert radios were also an effective alerting method for areas having access to the signals transmitted by the National Weather Service (Paul, 2003). Pricing of weather radios started at $19.99 for simple portable versions and a fully optioned model cost $69.99 (Radio Shack, 2008). Several grants were available through the Federal Emergency Management Agency (Federal Emergency

Management Agency, 2007), U.S. Department of Agriculture (U.S. Department of Agriculture, 2007), and U.S. Department of Health and Human Services (U.S. Department of Health and Human Services, 2002) for funding of the aforementioned devices.

Procedure

Feedback Form

A feedback form (Appendix) was developed by the researcher to gather data on tornado preparedness activities and warning systems, and to provide information to answer the research questions. Specifically the instrument was designed to assess preparedness and response planning programs and their components, as well as tornado warning systems used throughout the United States and their associated cost. The feedback form contained 24 questions divided into three sections. The first section was designed to gather demographical and contact information for each agency participating in the study and contained eight questions. The second section contained ten questions in support of the second and third research questions regarding tornado warning systems and associated funding options. The third and final section contained five questions designed to gather information in support of the first research question concerning tornado preparedness and response planning.

The first section contained questions 1 through 8 developed to gather demographical information such as type of agency, jurisdictional composition, and population make-up. Question 1 had nine components designed to gather contact information and all were short answer/fill-in. Questions 2 and 3 were also short answer/fill-in. Questions 4, 5, and 6 were multiple choice/single answer and all responses were converted to a percentage for each possible answer, each totaling 100%. Question 7 was multiple choice/multiple answer allowing the respondent to select any item that applied. As a result, after all responses were converted to

percentages, the totals had the potential of equaling more than 100%. For example, a respondent was able to state their jurisdiction was comprised of city limits, unincorporated areas, and tribal lands. Question 8 was also multiple choice/multiple answer allowing more than one selection per respondent, each of which was converted to a percentage. Furthermore, each choice category was broken down into the subcategories of 0-25%, 26%-50%, 51%-75%, and 75%-100%. Each respondent was required to provide the percentage of agricultural/undeveloped, residential, commercial, industrial, and other land uses in their jurisdiction. Questions 4, 5, and 7 also contained an "other" response which allowed respondents to provide answers that were not listed in the provided choices.

The second section contained questions 9 through 18, each developed using information gathered in the literature review which recommended types of tornado warning systems currently used in the United States. Questions 9, 11, 14, and 15 were multiple choice/single answer and all responses were converted to a percentage for each possible answer, each totaling 100%. Questions 12, 13, 16, 17, and 18 were multiple choice/multiple answer allowing the respondent to select any item that applied, and all responses were again converted to percentages. As a result the percentages had the potential of equaling more than 100% in each question. Responses to question 10 were not converted to percentages, instead raw numbers provided by the respondents were used in the analysis. Questions 12, 13, 16, 17, and 18 also contained an "other" response which allowed respondents to provide answers that were not listed in the provided choices.

The third section of the feedback form contained questions 19 through 23 designed to gather data in support of the first research question concerning components of preparedness and response programs. These questions were also developed using information gathered in the literature review. Question 19 was multiple choice/single answer and all responses were

converted to a percentage for each possible answer, each totaling 100%. Questions 20, 21, 22, and 23 were multiple choice/multiple answer allowing the respondent to select any item that applied, and all responses were again converted to percentages. As a result the percentages had the potential of equaling more than 100% in each question. Question 24 was short answer/fill-in and was designed to allow participants the ability to add any additional information they felt was pertinent to the research project. Questions 20, 21, 22, and 23 also contained an "other" response which allowed respondents to provide answers that were not listed in the provided choices.

The feedback form was created using *Survey Monkey*, an Internet program allowing members to design, distribute, and collect data from surveys. Once the feedback form was designed, it was posted on the National Society of Executive Fire Officers' website as well as distributed to members of individual state emergency manager's associations. These organizations were selected due to their cross-section of members who were involved in management and planning for tornadoes throughout the United States.

Data was collected for a period of three weeks and was later analyzed and compared to information presented in the literature review in order to determine whether preparedness and response programs and tornado warning systems being used by other communities compared to those utilized by, available to, or considered by the Frederick-Firestone Fire Protection District.

Population

A convenience sample was used for this study. The sample population, selected from fire service personnel and local and state emergency managers, was 86 (n=86). Due to the difficulty and cost of contacting each fire chief and emergency manager by mail, a sample of these groups was selected by contacting the National Society of Executive Fire Officers and state emergency managers associations. After the sample was selected, feedback forms including a cover letter

explaining the purpose and giving instructions for the form were e-mailed to members and posted on the organizations' websites. Of the respondents who linked to the survey, 82 were completed by the deadline.

Statistical Analysis

Descriptive statistics were used to calculate and interpret the data generated from the feedback form. The responses for each question were tabulated and each multiple choice question was converted to a percentage where applicable. Each response for the "other" responses to questions 12, 13, 16, 17, 18, 20, 21, 22, and 23 was also tabulated and converted to a percentage.

Limitations

As a result of the inability to distribute a feedback form to every fire chief and emergency manager in the United States, the sample population was small compared to the total number of persons in the target groups. Furthermore, the feedback form took approximately 30 minutes to complete, which may have discouraged some prospective recipients from completing it. An additional limitation was other potential managers of tornado preparedness and response programs and tornado warning systems such as law enforcement agencies, public works agencies, and government administrators were not included in the sample population. Finally, the researcher assumed all respondents answered honestly.

Definition of Terms

Fixed Directional Siren – A tornado siren on a stationary mount that either sends an audible signal in one direction or multiple directions through one or several speakers mounted on the siren head.

Hazard Vulnerability Analysis – A study of those hazards felt to be the greatest potential threat to a community, the environment, personal and public property, and or economy.

Mitigation Activities – Procedures or practices put in place to diminish or contain the negative effects of an emergency.

Preparedness Program – A procedure used prior to an emergency in order to pre-plan for a potential emergency in hopes of preventing negative impacts.

Recovery Activities – Procedures or practices put in place to rebuild and stabilize an area after an emergency incident.

Response Program – A pre-defined procedure implemented at the beginning of an emergency in order to specify resources, assignments, and operational procedures to handle the emergency.

Reverse 9-1-1 – A proprietary software program allowing responders to define a threat area, assign a group of people who are in the threat area, and then send outbound messages and instructions to the designated individuals until using the dispatch center's Enhanced 9-1-1 System.

Rotational Siren – A tornado siren on a rotating mount that sends an audible signal in multiple directions through one or several speakers mounted on the siren head.

Special District – A quasi-governmental agency established by state law for the purpose of providing local government services having three features in common. First, each is located in a defined geographic area or "district" within a municipality or, in some cases, more than one municipality. Second, each serves as a funding vehicle and operational means by which certain public improvements and/or services are provided to benefit the inhabitants of the district. And

third, real property within the district is subject to a “special” levy or assessment to finance the “special” improvement.

Tornado Touch Down – A tornado reported on the ground.

Tornado Warning – A waterspout is headed toward landfall or a funnel cloud is reported in the sky.

Results

A total of 82 feedback forms were completed in the specified time frame. Seventy-nine or 96.3% of the respondents provided contact information for question 1. Table 1 displays the distribution of States represented in the research.

Table 1

States Represented in Research		
State	Number of Respondents	Percentage of Total
Alabama	1	1.2%
Arkansas	1	1.2%
Arizona	6	7.4%
California	2	2.4%
Colorado	5	6.1%
Connecticut	1	1.2%
Florida	6	7.4%
Georgia	1	1.2%
Idaho	1	1.2%
Illinois	2	2.4%
Indiana	1	1.2%
Kansas	18	22.1%
Maine	1	1.2%
Maryland	1	1.2%
Michigan	2	2.4%
Minnesota	2	2.4%
Missouri	2	2.4%
Montana	1	1.2%
North Carolina	1	1.2%
New Hampshire	2	2.4%
Nevada	1	1.2%
New York	2	2.4%

Ohio	3	3.7%
Oregon	1	1.2%
Rhode Island	1	1.2%
Tennessee	5	6.1%
Texas	3	3.7%
Washington	3	3.7%
Wisconsin	3	3.7%
Unspecified	3	3.7%

All of the respondents answered the second question: “What is your rank and/or title?” For question 3, “What is the name of your agency?” 98.8% of those participating answered. Question 4 asked: “What type of agency do you represent?” Of those who answered, 95.1% represented a fire department and 4.9% represented an emergency management agency. Question 5, focused on the types of jurisdictions represented, and of those responding 13.4% were from special districts, 70.7% represented municipal departments, 9.8% represented county departments, 1.2% represented state agencies, and 4.9% represented other types of agencies including tribal governments, township departments, and joint power authorities.

Concerning type of staffing used by each representative agency in question 6, 8.5% were volunteer only, 48.8% were career only, and 42.7% were combination career and volunteer. Question 7 was “What type of area does your agency cover?” and 63.4% of those participating answered town or city limits, 15.9% answered county/unincorporated area, 5.1% answered state lands, 29.1% answered combination city limits and unincorporated area, and 1.2% answered “other”, classified as tribal reservation lands.

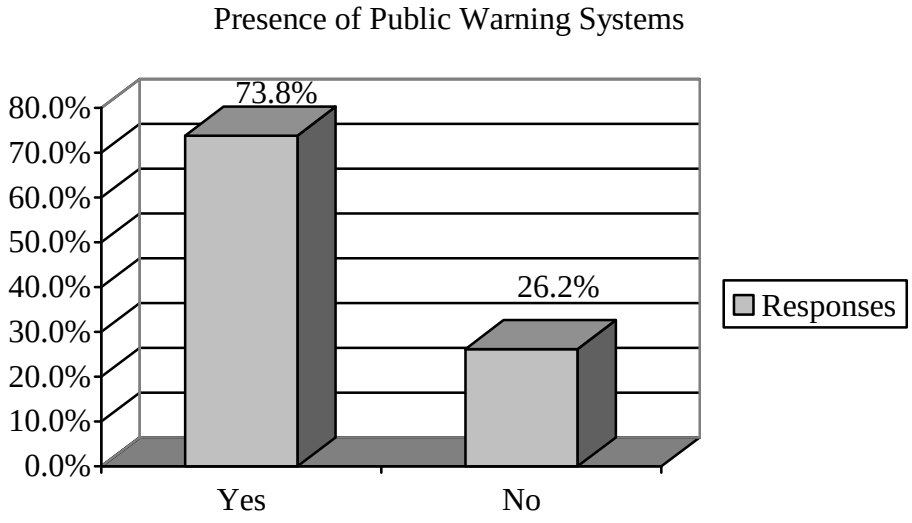
Question 8 was the last question in the demographic section of the feedback form, and asked “What percentage of the following areas are distributed throughout your jurisdiction?”

Those jurisdictions containing between 0%-25% agricultural land represented 55.9% of the participants, 23.5% contained between 26%-50% agricultural land, 10.3% contained between 51% and 75% agricultural land, and 10.3% stated their jurisdictions were 76%-100% agricultural land. Residential area comprising between 0%-25% of total area was present in 16.7% of those participating, 34.6% contained between 26%-50% residential area, 33.3% of respondents stated having 51%-75% residential area, and 15.4% contained between 76%-100% residential area. Those jurisdictions containing between 0%-25% commercial land represented 80.8% of the participants, 19.2% contained between 26%-50% commercial land, and none of the participants' jurisdictions contained more than 50% commercial land. Industrial area comprising 0% of total area was present in 10.3% of those participating, 89.7% contained between 1%-25% industrial area, and none of the participants' jurisdictions contained more than 25% industrial area.

Questions 9 through 18 were designed to assess various aspects of tornado warning systems being used throughout the United States. Question 9 asked participants if their jurisdiction had experienced any tornado warnings in the past five years. Of those who responded, 61.2% answered yes and 38.8% answered no. Question 10 asked those who answered yes to question 9, how many tornado warnings and touch downs they experienced over the same five year period. According to the respondents, there were 686 tornado warnings and 62 tornado touch downs in those jurisdictions represented over the past five years.

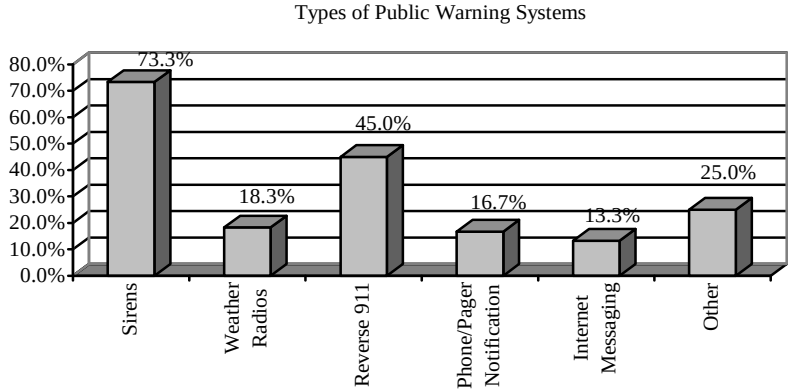
Question 11 asked participants if their jurisdiction contained a public warning system to warn the public in the event of a tornado threat. Of those answering, 73.8% answered yes and 26.2% answered no. Figure 1 displays the responses to question 11.

Figure 1



Those answering yes to question 11 were asked what type of warning system their jurisdiction used in question 12, of which 73.3% selected sirens, 18.3% selected weather alert radios, 45% selected Reverse 9-1-1, 16.7% selected cell phone/pager alerts, 13.3% selected Internet based messaging, and 25% selected "other" which included the Emergency Alert System, television and radio broadcasts, and cable override systems. Figure 2 displays the responses to question 12.

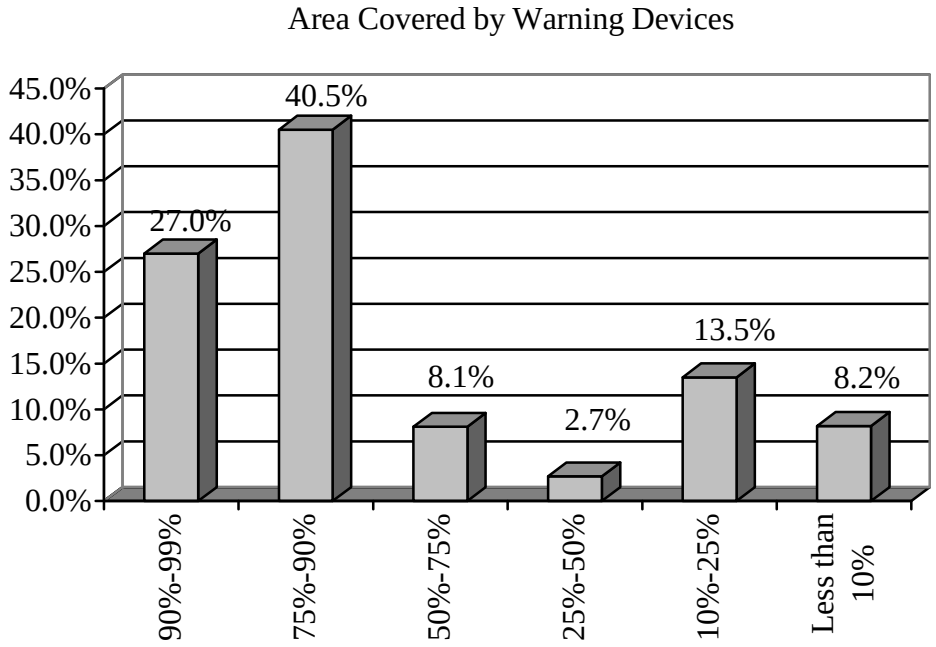
Figure 2



Question 13 asked those who used sirens, what type their jurisdiction used. 28.9% stated they utilized a fixed siren and 82.2% used a rotating siren. Additionally, 11.1% stated their sirens had voice instruction capability.

When asked whether their public warning system reached all areas of their jurisdiction in question 14, 54.5% of the respondents answered yes and 45.5% answered no. Question 15 asked those who answered no to question 14 what percentage of their jurisdiction was covered by their public alert system. Twenty-seven percent of those answering stated their public warning system covered between 90%-99% of their jurisdiction, 40.5% stated between 75%-90% of their jurisdiction was covered, 8.1% stated between 50-75% was covered, 2.7% stated between 25%-50% was covered, 13.5% answered between 10%-25% was covered, and 8.2% stated less than 10% of their jurisdiction was covered by their public alert system. The responses to question 15 are displayed in Figure 3.

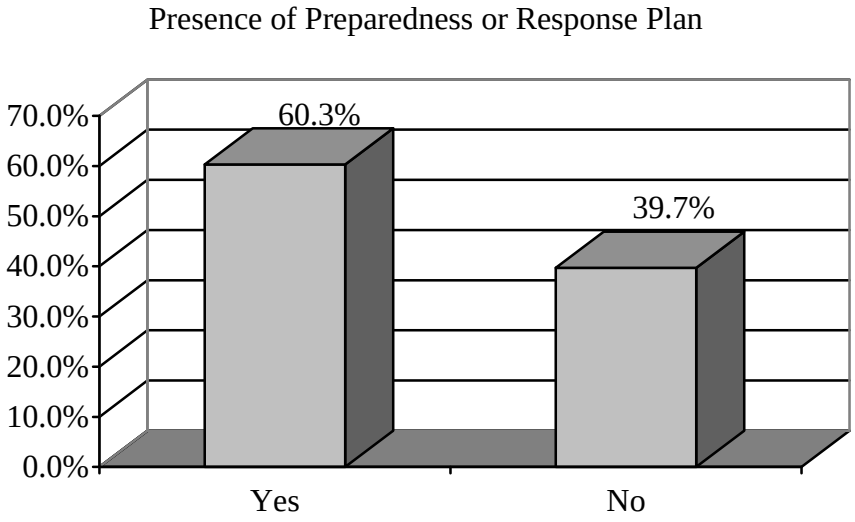
Figure 3



Questions 16, 17 and 18 inquired about funding mechanisms for public warning systems for those participants who stated their communities used such systems in question 11. Question 16 asked which agency in the participant's jurisdiction was responsible for funding the purchase of public warning system components. Fire departments were the responsible agency in 36.8% of jurisdictions, 13.2% stated their police department was the funding agency, 52.9% stated their emergency management department was responsible for funding, and 30.9% stated other departments such as administration or public works departments were responsible. Question 17 asked from where was funding for the purchase of the public warning system was derived. Forty-six percent stated initial purchase for their community's public warning system came from grants, 87.3% stated funding was from the general government funding, 1.6% stated funding was derived from bonds or loans, and 9.5% stated funding came from donations from civic groups, impact fees, and 9-1-1 fees. Question 18 asked who was responsible for funding the maintenance of the participant's public warning system. The fire department was responsible for this funding in 30.6% of those participating, 14.5% stated their police department was responsible, 46.8% stated their emergency management was responsible, 37.1% stated the general government administration was responsible, and 1.6% stated a utility company was responsible for maintenance funding.

The third and final section of the feedback form, containing questions 19 through 23, was designed to assess types and components of tornado response and preparedness programs currently being used in the United States. Question 19 inquired if the participant's jurisdiction had a tornado preparedness and response plan. Of those who responded, 60.3% stated yes and 39.7% stated no. Figure 4 displays the responses to question 19.

Figure 4

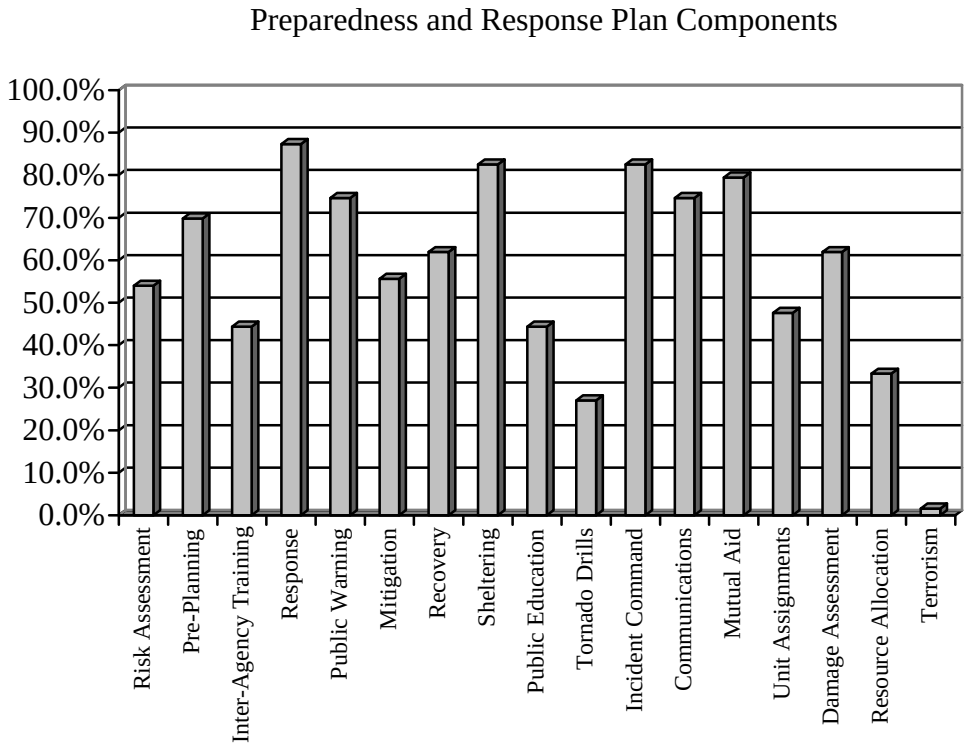


For those who responded yes to question 19, question 20 asked who was responsible for maintaining and overseeing their community's emergency response and preparedness plans. The fire department was partially or completely responsible according to 72.2% of respondents, the police department had responsibility in 16.7% of communities, the emergency management department was responsibly in 56.9% of communities, and other departments not listed above were responsible for maintaining and overseeing the plan in 8.3% of communities.

Question 21 asked participants what components were contained in their emergency response and preparedness plans. Fifty-four percent answered risk assessment was a component, 69.8% selected pre-planning, 44.4% selected inter-agency training, 87.3% selected response guidelines, 74.6% selected public warning, 55.6% selected mitigation actions, 61.9% selected recovery actions, 82.5% selected sheltering activities, 44.4% selected public education, 27% selected tornado drills, 82.5% incident command procedures, 74.6% selected communication procedures, 79.4% selected mutual/automatic aid procedures, 47.6% selected unit assignments,

61.9% selected damage assessment, 33.3% selected resource allocation priorities, and 1.6% selected terrorism preparedness. Question 22 asked if the elements present in the participant's emergency response and preparedness plan were developed internally, through a state program, a federal program, or other existing program. Forty-five percent stated their plan was developed using portions of an existing state program, 25% stated components of a federal program were used, and 93.3% stated their plan was developed locally developed programs. Target audiences of preparedness and response plans were reviewed in question 23. Eighty-three percent of the participants said their plan targeted citizens age 55 and older, 49.1% stated their plan targeted the 19 to 54 age group, 81.1% stated their plan targeted the age 1 to 18 age group, 54.7% stated their plan targeted the business and industrial community, and 1.9% were unsure of who their plan's target audience was. The responses to question 21 are displayed in Figure 5.

Figure 5



The final question in the survey was designed to allow participants the ability to add any additional information they felt was pertinent to the research project. Seventeen percent of the participants added comments to this section, and those pertinent to the study are listed in Table 2.

Table 2

Responses to Question 24
1. We had a tornado hit us on April 11, 1999, which damaged 55 structures, including the loss of 5 structures (The F4 reduced to an F2 as it hit our community).
2. Our city works in cooperation with county emergency management in placing spotter in the field, siren activation and communicating information to other agencies throughout the county.
3. We have the ability to sound the alarm for only a portion of the area or for the entire area, this way we don't unnecessarily warn folks that won't be in danger by the path of the storm.
4. Unfortunately Norfolk lacks any means for transmitting an audible alert to the community. we do have a community telephone notification program similar to reverse 911 (CTY)
5. South Florida is not prone to strong tornadic activity. However, due to frequent tropical storms and hurricanes, tornados are possible and we maintain the same level of response for these events.
6. The December 25, 2006 and February 2, 2007 tornados were a tremendous

test to preparing for such disasters. Interagency COOPs and media pro activity are an asset in preparation and recovery initiatives. In addition, the Unified Command System worked real well whereby fire, police, and the EOC (Emergency Operations Center) worked well and communicated effectively throughout the incident.”
7. Your question 14 on coverage of the notification system is only relative to people who may be engage or subscribed to available systems. It is also related to whop may be weather aware and listening to the radio for warnings. We allowed a costly siren system to go into disrepair and then deferral after strong development and 40 years of use of the civil defense alerting systems. Technology can replace this through some of the areas you identified. We employ both notification through the cells, email, pagers etc and reversed 9-1-1 but the residents need to enroll or subscribe to the alert system. This depends critically on public education which we struggle in our 1,000,000 population county to sustain.
8. We do not keep count of actual tornado warnings, so the number 50 is a best guess. We have also not had a confirmed tornado touchdown, but we have had a lot of "straight line wind" damage, including downed power lines of a large area of the county. This occurred in July 2003. The only confirmed tornado touchdown in Germantown occurred in November 1994 and killed 3 people and did over $50 million in damage.
9. We don't have tornados, but we do have significant wildfire risk, as well as

severe storm exposures (flash flooding, tides, wind, etc.)
10. We are going through a warning at this time.
11. No tornado problem or preparation in my area. If the survey were to include only high winds, I would have a little more input, but nothing on warning devices. Flooding would be a different story altogether.
12. The Northeast Region has strongly recommended NOAA Weather Radios for citizens. The cost of sirens and warning systems are nearly prohibitive for local government. NOAA radios costs vary from $20-$30 per individual household, and 90% of the region is now covered by NOAA transmitters. Nearly 90% of education facilities and local government facilities have a NOAA radio provided by grant funds through DHS and State Mitigation funds.

Discussion

Of those participating in the research, the majority represent combination or career fire departments in residential areas in low density areas with a moderate commercial base as identified by questions 4-8 on the feedback form. About two-thirds of the participants have emergency response and/or preparedness plans according to the responses to question 19. The more disturbing statistic derived from question19 is nearly 40% of the communities responding lack either a tornado preparedness or response plan. The data collected from question 20 also supports the assertion that fire departments play an active role in developing and maintaining those plans, even though in many cases they share responsibility with other agencies. This is

supported by Hnatko (2006), who advocates a multi-agency, multi-discipline approach to emergency planning, training, and coordination.

The literature review reveals many recommended components of tornado preparedness and response plans in support of the first research question including: hazard/vulnerability analysis, pre-planning (Hnatko, 2006), and public education (Mosier, 2002). These recommendations are consistent with actual planning activities in practice across the United States today according to data collected from the feedback form. Over half of all participants indicate they incorporate these components in their plans. Additionally, many other components are identified in the research derived from question 21, which warrants inclusion in preparedness and response planning in the FFFPD. In excess of 50% of the respondents indicate response procedures, public warning procedures, mitigation activities, recovery activities, sheltering procedures, incident command procedures, communication procedures, mutual aid procedures, and damage assessment procedures are integral components of their planning process. This supports the multi-faceted approach to the planning process advocated by Mosier (2002). The research also supports using a combination of existing programs as well as those adapted to and developed for specific hazards faced by the local community. Furthermore, responses to question 23 display a trend toward a multi-target approach to planning instead of focusing on one at-risk group. This is especially important since disasters such as tornadoes have wide reaching impacts on an entire community, even though each target group requires specific considerations based on their needs or limitations.

An important lesson learned in both the research and literature review is the principle any tornado preparedness plan must include a both extensive hazard analysis and strong public education components. Hitatko (2006) supports maintaining an emergency response plan

addressing each event identified in the hazard analysis stating, “Your emergency response plan should dictate how you will respond. A ‘make it up as we go’ plan is a plan for failure’” (Hitatko, 2006, p.79). Furthermore, there are many planning and preparedness activities the public can implement individually to protect themselves, their families, and their businesses in the event of a tornado threat. An extensive public education program teaching the importance of developing family and business disaster or emergency plans containing detailed checklists, individual assignments, communication procedures, supply kits (American Red Cross, 1997), and most importantly training and testing of the plan (Brubaker, 1997) can increase the effectiveness of a local government plan by creating a prepared community. In the case studies conducted by Comstock (2005), Paul, et al. (2003), Simmons and Sutter (2007), Kosik (1997), and Rigg (1997), the conclusions support public reaction to tornado threats and the aftermath is driven by their perception of the seriousness of the threat, the assumption of warning system capabilities, and the perceptions of the capabilities of responders.

The positive effects of proper preparedness planning is evident in a comparison of two devastating tornadoes that struck two communities; one in Alabama and the other in New Jersey. In Piedmont, Alabama, an area seldom affected by tornadoes, the community and responders were ill-prepared for the devastating impact a tornado posed to their community and lacked pre-planning and hazard analyses for such an event (Rigg, 1997). As a result, the community experienced longer-lasting negative effects and more serious injuries. The community and responders, although exhaustive and extremely dedicated in their efforts, lacked the specialized training and equipment necessary to deal with the extensive structural damage and associated rescue needs (Rigg, 1997). In contrast, East Brunswick, New Jersey which also rarely experienced a tornado threat prior to September 8, 1996, maintained an extensive all-hazards

emergency operations plan which coordinated response efforts of all agencies in the community (Kosik, 1997). The plan included a provision for a public education program that instructed the public about threats, associated hazards, and recommended precautionary actions. Even though the damage was extensive in both communities, response during the immediate aftermath of the strike in East Brunswick guided by the emergency operations plan led to orderly damage assessment, rescue, and sheltering operations resulting in a reduced human impact, and quicker recovery (Kosik, 1997).

Further support for the importance and effectiveness of tornado preparedness and response planning comes from Christopher J. Weir, Division Chief for the City of Port Orange (Florida) Department of Fire & Rescue. In response to question 24, Chief Weir states: "The December 25, 2006 and February 2, 2007 tornados were a tremendous test to preparing for such disasters. Interagency COOPs and media pro-activity are an asset in preparation and recovery initiatives. In addition, the Unified Command System worked real well whereby fire, police, and the EOC (Emergency Operations Center) worked well and communicated effectively throughout the incident."

In support of the second research question, nearly three quarters of the communities use some type of tornado public warning system. Again, the more disturbing statistic being over 25% of those participating in the study have no tornado warning system in place as signified by question 11. Of the 686 tornado warnings over the past five years reported by the respondents, nearly 10% were actual touch downs. The literature review reveals the most publicly recognized and used types of tornado warning systems in use today are television and radio broadcasts, tornado sirens, phone and pager alerts, weather band radio, and observable weather changes (Comstock, 2005). The data in question 12 of the feedback form supports Comstock's findings

affirming the most commonly used tornado warning systems in their communities are: tornado sirens, weather band radios, television and radio broadcasts, and phone and pager notifications.

The most prevalent type of tornado warning system used by respondents is outdoor rotational warning sirens, even though only 27% have siren systems that cover their entire jurisdiction as indicated in questions12 through 15. A limitation of siren systems as a primary public warning method is their diminishing effective audible range. The maximum effective range of tornado sirens currently manufactured is approximately 1 mile in optimum conditions (Audiotech Digital Signal Corporation, 2008). This range decreases with distance, wind, ambient noise levels, and land features/obstructions (Paul, et al., 2003). Additionally, sirens are an outdoor warning method and are not designed to be heard indoors, especially given the sound proofing materials used in building construction today (Simmons and Sutter, 2007). A further limitation of sirens is their ineffectiveness in providing specific details or instructions to the public (Comstock, 2005). These limitations, combined with a per unit cost of approximately $13,000 can make such systems cost prohibitive for many communities and still leave large portions of their communities unwarned. As an example, for the communities of Frederick and Firestone to upgrade their siren system to fully cover the 30 square mile jurisdiction would require the addition of approximately 18 sirens at an initial equipment cost of over $230,000. Add to the figure land or lease acquisitions to place the equipment, equipment installation, monitoring and activation equipment, and continuing maintenance costs, and the initial cost of such a system easily exceeds $500,000.

The contradiction remains that the public typically recognizes sirens as the means they will be alerted in the event of an approaching tornado (Paul, et al., 2003), even though such systems are not widely accepted as the most effective means of warning the public. The best

means to overcome this paradox is through educating the public of better warning methods, and actions they can take to recognize signs of potential tornado activity and to prepare their households or businesses (American Red Cross, 1997).

The most effective public warning systems are those incorporating multiple alerting methods (Mosier, 2002). Television and radio broadcasts, including the Emergency Alert System and cable override systems, are the most effective public alert systems considering the widespread availability of commonly used equipment in most households and businesses (Mitchem, 2003). This, in conjunction with the aforementioned education program will reach the largest portion of most populations. Even with these methods, there are still potential situations where individuals may not receive warning of an impending tornado, namely, if a tornado strikes at night when the majority of people are asleep. In these cases, the use of a weather alert radio, like a smoke detector, will be the most effective alerting method in areas where National Weather Service transmitters are present(Simmons and Sutter, 2007). According to Kevin Kuretich of the Colorado Division of Emergency Management in response to question 24: “The Northeast Region (Colorado) has strongly recommended NOAA Weather Radios for citizens. The costs of sirens and warning systems are nearly prohibitive for local government. NOAA radios costs vary from $20-$30 per individual household, and 90% of the region is now covered by NOAA transmitters.”

In support of the third research question concerning available funding methods for tornado warning systems, most of the respondents indicate in question 17 funding comes from their general budget. Additionally, funding is often shared among various departments including police, fire, public works, and emergency management as stated in the results of questions 16 and 18. The second most used funding mechanism identified in question 17 is state and federal

grants, accounting for 46% of the funding used by those agencies participating in this research project. As portrayed in the earlier estimation of what a siren system alone would cost the Frederick and Firestone area, many communities simply cannot absorb adding such a system to their general operating budgets. As a result, grants are the only viable funding mechanism for most communities. However, available grant money is limited and often based on how many people are impacted by the proposed program. Often, small communities lose out in the selection process to larger, more densely populated cities because of the potential higher loss of life in those areas (Paul, et al., 2003). The fact remains that most communities never research or apply for grants due to a lack of knowledge of their availability, apprehension to undertaking the process, lack of access to a qualified grant writer, or an attitude they will not be successful. The potential consequence is a portion of available grant money may be redistributed each year because of a lack of applicants. Several grant resources are identified in the literature review including the Hazard Mitigation Grant and Pre-Disaster Mitigation Grant programs (Federal Emergency Management Agency, 2007) and the Rural Development Grant (U.S. Department of Agriculture, 2007). Another useful grant resource is *Grants.gov* offered through the U.S. Department of Health and Human Services (2002). Kevin Kuretich of the Colorado Division of Emergency Management commenting in question 24 states: ”Nearly 90% of education facilities and local government facilities (in Colorado) have a NOAA radio provided by grant funds through DHS (Department of Homeland Security) and State (of Colorado) Mitigation funds.”

Other funding methods identified in question17 include impact fees, a portion of 9-1-1 fees, and donations and fund raising campaigns from civic groups. In the aftermath of the tornado that hit Piedmont, Alabama, public sentiment was raised to such a high level, due to the

devastating number of fatalities, an entire emergency warning system was purchased solely through public donations (Rigg, 1997).

Recommendations

Given the communities of Frederick and Firestone exist in an interface region of two wind fronts, the Denver Cyclone and the Longmont Anticyclone, both of which produce wind conditions associated with tornado production (Parzybok, 2005), the Frederick-Firestone Fire Protection District in cooperation with other local agencies should develop a comprehensive tornado preparedness and response plan. This plan should exist as a component of an all hazards emergency operations plan as recommended by Kosik (1997). The research presented in this study suggests the tornado plan should contain two general categories: public education on family and business preparedness activities and governmental agency preparedness and response planning. The public education component should include instructing the public on developing a family and business disaster plan each containing safety checklists, an alerting method to warn members of tornado activity, pre-designated safe places to go to during a tornado's approach, the provision for a disaster kit to sustain needs for at least 72 hours, a communications plan for after a tornado has struck, and a meeting place should members become separated. Public education programs should also include instruction on recognizing weather conditions associated with tornado activity, and how to conduct routine drills and training. The research suggests one of the most effective warning systems is for individuals to recognize changing weather and know what precautions to take independently.

The second component of a tornado plan for the Towns of Frederick and Firestone is procedures directing local agencies in tornado preparedness and response activities prior to, during, and after a potential tornado strike. The research suggests such a plan should include

procedures for conducting a comprehensive hazard analysis and capability analysis to identify potential hazards in the community and the local responders' ability to mitigate such hazards should a tornado strike. Next, the tornado preparedness and response plan for Frederick and Firestone should include sections on public warning procedures, response procedures, incident command procedures, emergency communication procedures, unit assignment priorities, hazard mitigation procedures, sheltering procedures, recovery priorities, damage assessment procedures, and inter-agency training.

In addition to a comprehensive tornado preparedness and response plan, the Frederick-Firestone Fire Protection District should work with other local agencies of the Towns of Frederick and Firestone to develop a multi-component public warning system to advise the public in the event of a tornado approaching the area. The current warning system in use in the area is not sufficient for warning the entire jurisdiction. This is a common problem in most communities using outdoor warning sirens. Most of these siren systems, including the one in use in Frederick and Firestone, were designed for civil defense use and are ineffective for warning persons indoors or at distances further from the siren's source. Additionally, the sirens deployed by the FFFPD do not have the capability to give detailed instructions or specific information about the warning itself. This contributes to creating an atmosphere of panic and curiosity at a time when individuals need to be taking organized, timely protective actions. Added to these shortcomings is the excessive cost of upgrading the current siren system in Frederick and Firestone. The limited current budget revenue can be better spent on other, more effective methods of warning and educating the public.

The system developed by the Frederick-Firestone Fire Protection District and other local agencies should include an integrated public education component promoting weather watching

techniques, promotion of reliance on television and commercial radio broadcasts, purchasing of government use software at the dispatch center capable of sending internet and text messages about weather alerts, a phone and pager registration program for receiving text warnings, and the use of weather alert radios. Initial education in Frederick and Firestone should extensively inform the public about the benefits of alternative warning systems and that the existing sirens are only intended to warn people outdoors in the downtown areas of both towns. The current misconceptions that sirens will be heard in the event of an approaching tornado, and sirens are the best means of warning need to be altered for any future system to be effective.

Alternate funding methods also need to be implemented by the Frederick-Firestone Fire Protection District as well as other local agencies in order to purchase messaging software, education programs, and weather alert radios to those who cannot afford them. The best source of alternate funding is through federal, state, and foundation grants. The research identifies several grants available for such programs, warranting investigation by the FFFPD. The Colorado Division of Emergency Management identifies grants available through DHS and State of Colorado Mitigation funds for weather alert radios. Another grant resource warranting utilization by the Frederick-Firestone Fire Protection District is *Grants.gov* in order to identify other grant programs. When considering the $500,000 initial cost and continuing maintenance costs of upgrading the current siren system, even the cost of providing weather alert radios to half of the 10,000 households and 370 businesses at a cost of $30 is much more manageable, and creates a much more effective and reliable alerting system.

Future research on the topic of tornado preparedness activities and tornado public warning systems should include a more detailed analysis of public education programs available to better prepare the public for tornadoes. Also, more research should be conducted on recovery

procedures designed to help communities recuperate after a tornado strike. A final topic for future research should include advanced sheltering and evacuation procedures for tornado impacted communities. It can be surmised from this research project that the trend of devastation resulting from tornado strikes will continue, which should motivate fire service and other government leaders to be vigilant in their pursuit of proactive programs to lessen the impact of this problem.

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Appendix

Tornado Preparedness and Warning Systems Questionnaire

Ted M. Poszywak
Frederick-Firestone Fire Protection District

I am currently enrolled in the Executive Fire Officer Program at the National Fire Academy. One of the criteria of the program is the completion of an applied research project. The following questionnaire is part of my applied research project for the Executive Analysis of Fire Service Operations in Emergency Management course and was designed to gather information regarding tornado preparedness and warning systems. It will take approximately 20 minutes to complete the questionnaire and your responses combined with those of other departments around the State will be used to provide others with information regarding available types of tornado preparedness activities and types of tornado warning systems. Your agency name and your contact information will only be used by me for follow-up questions and clarification if necessary, and will not be included in the final paper. Thank you in advance for your time and assistance.

Section 1 – Demographic Information

1. What is your contact information? (optional)
    a. Name: *92.7%*
    b. Address: *91.5%*
    c. Address 2: *9.8%*
    d. City/Town: *92.7%*
    e. State: *96.3%*
    f. ZIP/Postal Code: *92.7%*
    g. Country: *87.8%*
    h. Email Address: *90.2%*
    i. Phone Number: *87.8%*

2. What is your rank and/or title? *100%*

3. What is the name of your agency? *98.8%*

4. What type of agency do you represent?
    a. ☐ Fire Service *95.1%*
    b. ☐ Emergency Management *4.9%*
    c. ☐ Other (please specify) *0.0%*

5. What type of jurisdiction is your agency?

a.	☐ Special District	*13.4%*
b.	☐ Municipal Fire Department	*70.7%*
c.	☐ County Fire Department	*9.8%*
d.	☐ State Agency	*1.2%*
e.	☐ Other (please describe): *Tribal Government, Township, Joint Power Authority*	*4.9%*

6. What type of staffing does your agency use?

a.	☐ Volunteer	*8.5%*
b.	☐ Career	*48.8%*
c.	☐ Combination	*42.7%*

7. What type of area does your agency cover? (select all that apply)

a.	☐ Town or City Limits	*63.4%*
b.	☐ County/Unincorporated Area	*15.9%*
c.	☐ State Lands	*5.1%*
d.	☐ Combination City Limits/Unincorporated Area	*29.1%*
e.	☐ Other (please describe): *Reservation*	*1.2%*

8. What percentage of the following areas are distributed throughout your jurisdiction?

a.	Agricultural/Undeveloped:	0%-25%	55.9%
		26%-50%	*23.5%*
		51%-75%	*10.3%*
		76%-100%	*10.3%*
b.	Residential:	0%-25%	*16.7%*
		26%-50%	*34.6%*
		51%-75%	*33.3%*
		76%-100%	*15.4%*
c.	Commercial:	0%-25%	*80.8%*
		26%-50%	*19.2%*
		51%-75%	*0%*
		76%-100%	*0%*
d.	Industrial:	0%	*10.3%*
		1%-25%	*87.3%*
		26%-50%	*0%*
		51%-75%	*0%*
		75%-100%	*0%*

Section 2 – Tornado Warning Systems

9. Has your jurisdiction experienced any tornado warnings or touch downs over the past five years?
    a. ☐ Yes *61.2%*
    b. ☐ No *38.8%*

10. If yes, how many of each of the following has your jurisdiction had in the past five years?
    a. Warnings: *686*
    b. Touch downs: *62*

11. Does your jurisdiction have a public warning system used to warn the public in the event of a tornado threat?
    a. ☐ Yes *73.8%*
    b. ☐ No *26.2%*

12. If yes, what type of warning system does your jurisdiction use? (select all that apply)
    a. ☐ Sirens *73.3%*
    b. ☐ Publically Distributed Weather Radios *18.3%*
    c. ☐ Reverse 9-1-1 *45.0%*
    d. ☐ Public Cell Phone/Pager Notification *16.7%*
    e. ☐ Internet Based Messaging *13.3%*
    f. ☐ Other (please describe): *Emergency Alert System, Television and Radio Broadcasts, Cable Override System* *25.0%*

13. If your jurisdiction uses warning sirens, what type are they? (select all that apply)
    a. ☐ Fixed Direction *28.9%*
    b. ☐ Rotational *82.2%*
    c. ☐ Siren Only *28.9%*
    d. ☐ Voice Instruction Capable *11.1%*
    e. ☐ Other (please describe): *0.0%*

14. Does your public warning system reach all areas of your jurisdiction?
    a. ☐ Yes *54.5%*
    b. ☐ No *45.5%*

15. If no, what percentage of your jurisdiction is covered by the warning system?
    a. ☐ 90%-99% *27.0%*
    b. ☐ 75%-90% *40.5%*
    c. ☐ 50%-75% *8.1%*
    d. ☐ 25%-50% *2.7%*
    e. ☐ 10%-25% *13.5%*
    f. ☐ Less than 10% *8.2%*

16. What agency in your jurisdiction is responsible for funding the purchase of public warning system components? (select all that apply)
    a. ☐ Fire Department *36.8%*
    b. ☐ Police Department *13.2%*
    c. ☐ Emergency Management Department *52.9%*
    d. ☐ Other Local Government Department *30.9%*
    e. ☐ Other Not Listed (please give department/agency name): *0.0%*

17. What type of funding is used for the purchase of public warning system components? (select all that apply)
    a. ☐ General Budget *87.3%*
    b. ☐ Bonds/Loans *1.6%*
    c. ☐ Grants *46.0%*
    d. ☐ Other Not Listed (please give describe): *Donations/Civic Groups, Impact Fees, 9-1-1 Fees, Unsure* *9.5%*

18. What agency in your jurisdiction is responsible for funding the maintenance of the public warning system? (select all that apply)
    a. ☐ Fire Department *30.6%*
    b. ☐ Police Department *14.5%*
    c. ☐ Emergency Management Department *46.8%*
    d. ☐ Other Local Government Department *37.1%*
    e. ☐ Other Not Listed (please give department/agency name): *Utility Company* *1.6%*

Section 3 – Tornado Response and Preparedness Planning

19. Does your department/jurisdiction currently have a tornado preparedness and response plan or Standard Operating Procedure (SOP)?
    a. ☐ Yes *60.3%*
    b. ☐ No *39.7%*

20. What agency is responsible for maintaining and overseeing the response and preparedness program? (select all that apply)
    a. ☐ Fire Department *72.2%*
    b. ☐ Police Department *16.7%*
    c. ☐ Emergency Management Department *56.9%*
    d. ☐ Other Local Government Department *8.3%*
    e. ☐ Other Not Listed (please give department/agency name): *0.0%*

21. Does your preparedness and response program/SOP address any of the following elements? (select all that apply)

a. Risk Assessment:	☐ Yes	☐ No	*54.0%*
b. Pre-Planning:	☐ Yes	☐ No	*69.8%*
c. Inter-Agency Training:	☐ Yes	☐ No	*44.4%*
d. Response:	☐ Yes	☐ No	*87.3%*
e. Public Warning/Alert:	☐ Yes	☐ No	*74.6%*
f. Mitigation:	☐ Yes	☐ No	*55.6%*
g. Recovery:	☐ Yes	☐ No	*61.9%*
h. Sheltering:	☐ Yes	☐ No	*82.5%*
i. Public Education:	☐ Yes	☐ No	*44.4%*
j. Public Tornado Drills:	☐ Yes	☐ No	*27.0%*
k. Incident Command:	☐ Yes	☐ No	*82.5%*
l. Communication Procedures:	☐ Yes	☐ No	*74.6%*
m. Mutual/Automatic Aid:	☐ Yes	☐ No	*79.4%*
n. Unit Assignment/Responsibilities:	☐ Yes	☐ No	*47.6%*
o. Damage Assessment:	☐ Yes	☐ No	*61.9%*
p. Priority of Resource Allocation:	☐ Yes	☐ No	*33.3%*
q. Other components not listed: *Terrorism*			*1.6%*

22. Were these elements developed internally, or adopted from existing national or state programs? (select all that apply)
    a. ☐ Internally/Locally *93.3%*
    b. ☐ State Program *45.0%*
    c. ☐ National Program *25.0%*
    d. ☐ Other (please explain): *0.0%*

23. What are the target groups of your preparedness program? (select all that apply)

a.	☐ Citizens Age 55+	*83.0%*
b.	☐ Citizens Ages 1-18	*81.1%*
c.	☐ Citizens Ages 19-54	*49.1%*
d.	☐ Business/Industry	*54.7%*
e.	☐ Government Employees	*52.8%*
f.	☐ Other Not Listed (please list): *Unsure*	*1.9%*

24. Is there any additional information you would like to add? *17%*

Thank you again for taking the time to complete this questionnaire. If you would like to receive the results of this study, you may request a copy after March 3, 2008 by contacting me at:

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